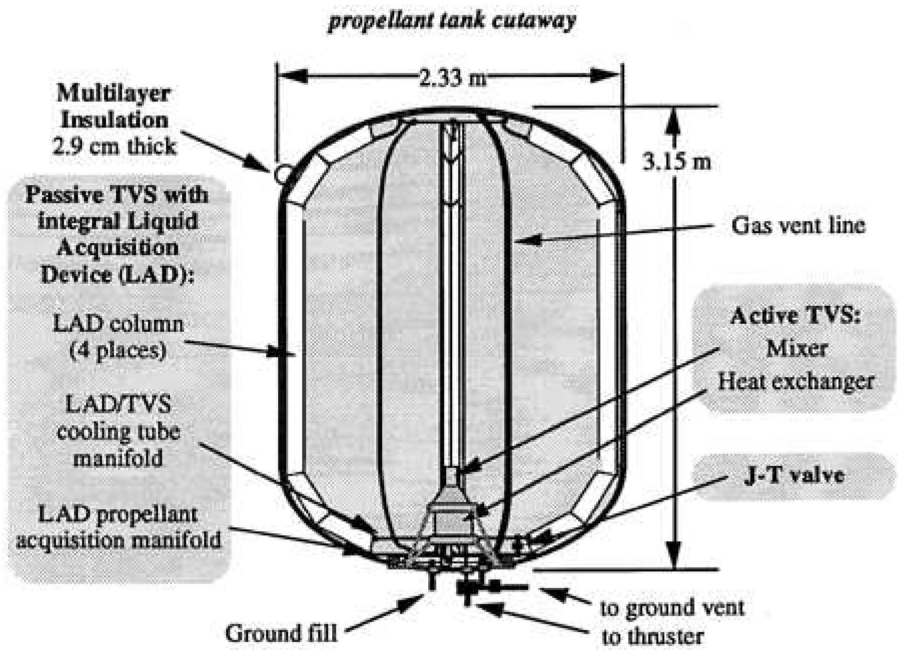
Thermodynamic Vent System Applied as Propellant Delivery System for Air Force

Responding to a request from the Air Force, NASA Lewis Research Center engineers designed a combination pressure control and propellant delivery system based on thermodynamic vent system (TVS) technology. The Air Force is designing a new type of orbit transfer vehicle that uses energy from sunlight to both propel and power the vehicle. Because this vehicle uses propellant at a substantially slower rate than higher-energy rockets, it needed the Lewis-developed TVS technology for long-duration storage of cryogen propellants. Lewis engineers, in conjunction with industry partners, showed how this TVS technology could also be used to deliver propellant to the thruster. The Air Force has now begun the ground test demonstration phase. After successful completion of ground testing, the Air Force plans to use this technology in a space flight as early as 1999.

To reduce satellite operation costs, the Air Force is designing an Integrated Solar Upper Stage (ISUS) to transport communication satellites from low-Earth orbit to higher operational orbits. This vehicle uses solar concentrators for both propulsive heating of the hydrogen propellant and thermionic power generation once the vehicle has reached its operational orbit. Because the payload and spacecraft system are integrated into a common unit and because the propulsion method has a higher specific impulse than conventional upper stages do, the Integrated Solar Upper Stage can use smaller and less-expensive launch vehicles to deliver the same mass as conventional upper stages.

For this application, the Air Force needed a propellant storage and delivery system with the following characteristics: (1) a minimum-volume, cryogenic liquid hydrogen tank, (2) no propellant venting except that which occurs as a part of orbit transfer burns, (3) a 30-day orbit transfer with a nonconstant burn schedule, (4) a high ratio of tank lockup durations to burn durations, and (5) the option to hold the propellants at low orbit for 3 to 7 days before the orbit transfer.



Thermodynamic vent system applied as propellant delivery system for air force integrated solar upper stage--propellant tank cutaway.

These challenges were met by the Lewis/industry team's conceptual design, shown in the figure. To minimize tank volume, the team used a low-pressure, low-ullage tank (0.3 MPa, 3-percent ullage). A multilayer insulation system reduces heat leaks into the tank, but it is designed to allow enough background heat into the tank to pressurize the system. A TVS, originally designed for controlling tank pressures for long-duration cryogen storage, simultaneously delivers propellant to the thruster and removes heat from the tank. The resulting pressure drop during each burn is tailored so that the operating pressure will be recovered by background heating before the next burn. Because of the nonconstant burn schedule and uncertainties about the heat rate and corresponding pressure rise in microgravity environments, a TVS incorporating an integral mixer and heat exchanger with an active controller is used. The mixer can also be used between burns to control tank pressure. A heater included in the system can add heat to the tank if needed.

The next major step of the program is the engine ground demonstration to be conducted in Lewis test facilities (1997). It will demonstrate vehicle operation over a simulated mission profile. Success of the ground testing may lead to a flight mission as early as 1999.